

## Chesapeake Campus – Chemistry 111 Laboratory

# LAB #7-TITRATION OF A CARBONATED BEVERAGE

---

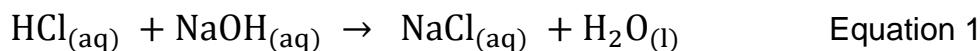
### Objectives

- Calculate the concentration of a secondary standard through titration with a primary standard.
- Titrate a sample of carbonated soda with a standard solution to determine the concentration of acid in the beverage.
- Distinguish between endpoint and equivalence point with the addition of indicator to your sample.

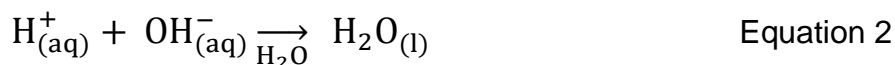
### Introduction

#### Neutralization Reactions

Acid–Base reactions are an important portion of chemistry. In aqueous solutions, a compound that produces  $\text{H}^+$  ions upon dissolution is termed an **acid**. A compound that produces  $\text{OH}^-$  ions when dissolved in water is called a **base**. The reaction of an acid and base is a **neutralization** reaction, the products of which are a salt and water. This is shown below:

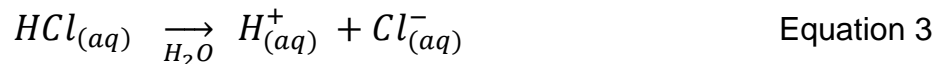


In an aqueous solution, virtually all of the  $\text{OH}^-$  ions present will react with all of the  $\text{H}^+$  ions that are present. Thus the net ionic equation of a strong acid reacting with a strong base is:



This reaction is essentially quantitative, which allows us to use these titrations to determine the concentration of an acid or base in an aqueous solution with high accuracy.

It is important to note that not all hydrogen atoms are considered acidic. Only acidic protons will disassociate from the compound and contribute to the reaction. Monoprotic acids produce one acidic proton per molecule. An example of a monoprotic acid is hydrochloric acid (HCl) which disassociates according to:



As shown in Equation 1, hydrochloric acid reacts with sodium hydroxide in a one to one ratio. We can tell from this balanced equation that when a solution of hydrochloric acid, HCl, is *exactly* neutralized with a solution of sodium hydroxide, NaOH, the number of moles of NaOH used will equal the number of moles of HCl originally present. This is also called the **equivalence point**.



For this experiment we can also expand this equation to

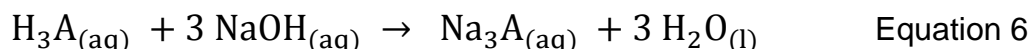
$$M_{\text{NaOH}} V_{\text{NaOH}} = M_{\text{HCl}} V_{\text{HCl}} \quad \text{Equation 5}$$

where M = concentration in molarity and V= volume in liters. If three of the above quantities are known, the fourth can be calculated.

### Classification of Acids

Not all acids are monoprotic. Diprotic acids produce two acidic protons in aqueous solution. We will be titrating a soda that contains citric acid, a triprotic acid. Acids are often added to carbonated beverages as an ingredient to give a sour “bite” or taste. Dark sodas typically add phosphoric acid while light colored and clear sodas tend to use citric acid. Citric acid is a triprotic acid which contains three acidic protons.

Citric acid reacts with sodium hydroxide according to the following reaction where A is assumed to be the citrate ion:



Notice that because citric acid is a triprotic acid the mole to mol ratio between the acid and base is 1:3 respectively. This will be important for your calculations.

In order to determine when a solution has been *exactly* neutralized, an **acid-base indicator** is used that changes color in a certain pH range (pH is a scale used to measure acidity). This color change is termed the **endpoint** of the titration. ( Ideally we would detect the equivalence point, but no indicator changes color at exactly the equivalence point, so instead titrations usually proceed 1-2 drops past the equivalence point to the endpoint which is when you can detect a color change). Because the pH of a neutral solution is 7, an indicator that changes color near this pH should be used for an acid-base titration. **Phenolphthalein** indicator changes color in the range pH = 8.3 – 10.0 and can be used to determine when the correct amount of base has been added to an acidic solution to exactly neutralize it.

### Preparation of Sodium Hydroxide Solution

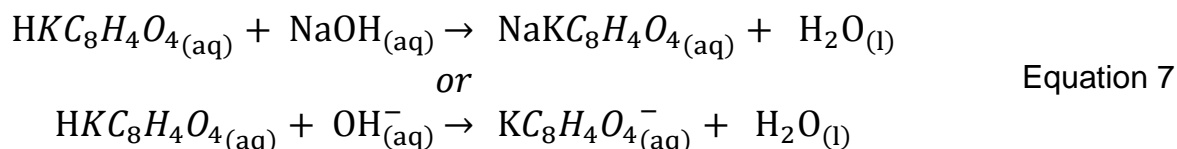
You will need ~ 200 mL of 0.04 M NaOH for this experiment. You will use a small amount of 2.5 M NaOH to make the more dilute solution for use in the procedure. In your prelab, you will calculate how to prepare this solution.

### Standardization of a Sodium Hydroxide Solution

It is difficult to accurately prepare a solution of sodium hydroxide since it is **hygroscopic** (absorbs water readily from air). Thus the solution of NaOH must be *standardized* (meaning the exact molarity must be determined) using a **primary standard**. A primary standard must satisfy the four following criteria:

1. Can be obtained as a solid compound that is not hygroscopic and can be easily handled.
2. Is available in very pure form.
3. Is chemically stable over time.
4. Has a medium to high molecular weight.

We will be standardized using potassium hydrogen phthalate, ( $\text{HKC}_8\text{H}_4\text{O}_4$ ) which is a monoprotic acid. The molecular weight of ( $\text{HKC}_8\text{H}_4\text{O}_4$ ) is 204.23 g/mole, and it has one **acidic proton**, which will react quantitatively with  $\text{OH}^-$ : Occasionally potassium hydrogen phthalate is abbreviated as KHP even though the formula is  $\text{HKC}_8\text{H}_4\text{O}_4$ .



For the highest accuracy, a sample size is chosen such that it will consume as large a volume of the base as possible without exceeding the capacity of the buret. If a 50 mL buret is used, the amount of KHP is chosen such that it will require approximately 15 mL of 0.04 M NaOH solution to reach the endpoint (so that ~ 3 trials can be completed without refilling the buret). Thus,

$$0.015 \text{ L NaOH} \frac{0.04 \text{ mol NaOH}}{1 \text{ L}} \frac{1 \text{ mol KHP}}{1 \text{ mol NaOH}} \frac{204.23 \text{ g KHP}}{1 \text{ mol KHP}} = 0.122 \text{ g KHP}$$

About **0.122 g** of KHP is needed. At the endpoint, the number of moles of NaOH equals the number of moles of KHP used:

$$M_{\text{NaOH}} = \frac{\text{mol KHP}}{\text{L NaOH ()}} \quad \text{Equation 8}$$

$$M_{\text{NaOH}} = \frac{\text{g KHP}}{204.23 \text{ g/mol}} * \frac{1000 \text{ mL/L}}{\text{mL NaOH}} \quad \text{Equation 9}$$

### Determination of the Acid Content of the Soda

In this experiment you will determine the concentration of citric acid in a soda. In order to do this we will titrate the soda with a standardized solution of sodium hydroxide. Most soda contains acid to provide a tangy taste. The soda used in this lab has citric acid (a triprotic acid) as a main ingredient. You can determine the concentration of  $\text{H}^+$  and citric acid in your soda sample using stoichiometry. Note that it is important that your sample of soda be flat. The presence of carbon dioxide gas in the solution will greatly affect your numbers. Soda should be heated to remove gas prior to its use.

### Confirmation that Citric Acid is Triprotic

Citric acid ( $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$ ) has three hydrogen atoms that can be dissociated in solution. You can titrate a small sample of citric acid with your standardized NaOH to determine if the acid really is triprotic (1 mol citric acid : 3 mol NaOH).

## **Materials**

- Student tray containing the following:
  - 1-50ml flask
  - 1 DI water bottle
  - \*Note that this is incomplete.
- Student balance

## **Safety and Notes**

- Sodium hydroxide is caustic. If it gets on your skin, flush with copious amounts of water and inform your instructor.
- All waste must be disposed of in the CHM 111 Waste container in the back hood.
- Return all materials to trays and drawers in a clean orderly condition for the next class.

## **Experimental Procedure**

### **A Preparation of the 0.040 M NaOH**

1. Use a 10 mL graduated cylinder to measure out ~ 3.2 mL of 2.5 M NaOH.
2. Add this to a 200 mL volumetric flask.
3. Fill the flask to the line with deionized water.
4. Cork the flask and carefully invert it several times to make sure the solution is homogenous.

### **B. Standardization of the 0.040 NaOH Solution**

1. NaOH is hygroscopic and absorb water from the air causing the concentration of any sodium hydroxide solution to change over time. It is necessary to calculate the exact concentration of NaOH by titrating with a primary standard.
2. Label two 50 mL flasks for Trial 1 and Trial 2. Measure between 0.1 and 0.13 g of KHP ( $\text{HKC}_8\text{H}_4\text{O}_4$ ).
3. Record the exact mass to 0.001 g in your data section.
4. Dissolve the KHP by adding ~ 15 mL water to the flask. You may need to swirl for several minutes to dissolve.
5. If there is KHP on the sides of the flask use a water bottle to help dissolve the solid.
6. Add 3-4 drops of indicator to each flask.
7. Check your buret to make sure it will not leak by adding deionized water to the top and allowing it to run out as shown by your instructor.
8. Carefully add ~ 50 mL of the ~ 0.040 M NaOH solution to a buret. Do not waste time getting it to the 0.0 mark. Instead record the exact volume (to two decimal spaces) in your data section.
9. Titrate the sample slowly until a pale pink color remains for at least 3 seconds. If you exceed the endpoint the color will be a dark pink and you will have to do a third trial.
10. Obtain instructor approval on the color of the solution before moving on.
11. Record the final volume of NaOH in the data section. You do not need to add more NaOH to the buret between trials. Use the final volume from the first trial as the initial volume for the second trial.
12. Use the volume of NaOH and grams of KHP to calculate the molarity of the NaOH solution. (If you need help, see the equations in your prelab).
13. Record the concentration of your standardized NaOH solution in your manual. You will use this molarity in Part C and Part D of today's experiment.

### C. Titration of a Carbonated Beverage

1. Obtain ~ 20 mL of soda. Record the brand of Soda in your data table.
2. If necessary heat the soda for 10 minutes to approximately 80 degrees C to remove carbon dioxide. This step is not necessary if your instructor has already performed this step for you.
3. Use a pipette or stirring rod to collect a drop of the cooled soda.
4. Touch the drop to a piece of pH paper. Record the pH of the beverage in your data section.
5. Use the pH to evaluate what the concentration of  $H^+$  in the soda should be. You will confirm this with your standardized NaOH.
6. Clean two 50 mL flasks. Label them **Trial 1** and **Trial 2**.
7. With a clean 10 mL graduated cylinder measure between 2.8 and 3.2 mL of soda.
8. Add the sample to your 50 mL flask. Be sure to record the exact volume of soda used for each trial.
9. Add 3-4 drops of indicator.
10. Add ~ 20 mL of deionized water to make the titration easier. (If the volume of the analyte is too small, it will be difficult to distinguish the color change).
11. Fill the buret with ~ 50 mL standardized NaOH. Record the initial volume in your data table.
12. Titrate the soda to a light pink color. Obtain instructor approval before moving on.
13. Record the final volume of the standardized NaOH in your data table.
14. Using the balanced equation calculate the concentration of acid in your soda sample.

### D. Titration of Citric Acid.

1. Obtain a clean 50 mL flasks.
2. Weigh out 0.05 g citric acid.
3. Dissolve the sample in ~ 20 mL of water. Add 3-4 drops of indicator.
4. Fill the buret with ~ 50 mL of standardized NaOH. Record the initial volume in your data table.
5. Titrate the citric acid to a light pink color. The color should be maintained for at least 30 seconds. If it fades to colorless, add another drop of sodium hydroxide to the sample.
6. Record the final volume of NaOH in your data table.
7. If time allows, do another trial.

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

### **Pre-lab Assignment/Questions**

\* *Note— this pre-lab must be finished before you come to lab.*

1. Calculate the molar mass of citric acid  $\text{C}_6\text{H}_8\text{O}_7$ .
2. Calculate the volume of 2.5 M NaOH needed to make 200 mL of 0.04 M NaOH.
3. The balanced equation for KHP and NaOH is given in the introduction to this lab. Calculate how much KHP is needed to react ~20 mL of 0.040 M NaOH.
4. The pH of flat sprite is usually 4.16. Calculate the  $\text{H}^+$  concentration in the beverage. (Remember that  $\text{pH} = -\log[\text{H}^+]$ ).
5. Citric acid, the main acidic component of Sprite, is triprotic. What is the concentration of citric acid in Sprite? (Hint: Use the molarity of  $\text{H}^+$  and the mol : mol ratio of citric acid to acidic protons to calculate it's concentration).

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

## **Experimental Data and Results**

### **A. Preparation of NaOH**

1. Concentration of Stock Solution	
2. Volume of Stock Solution Used	
3. Volume After Dilution	200.0 mL
4. Final Concentration (approximate)	

\*Show calculation

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

**B. Standardization of NaOH**

	Trial 1	Trial 2	Trial 3 (only necessary if instructor does not give approval for one of the previous trials).
1. Mass of KHP			
2. Mol KHP			
3. Mol NaOH			
4. Initial Volume NaOH			
5. Final Volume NaOH			
6. Volume NaOH Used			
7. Instructor Approval of Endpoint			
8. Molarity of NaOH			

\*Show all calculations

Average Concentration of NaOH \_\_\_\_\_

\*Show your work.

\*This is the concentration of NaOH you use in C.



Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

**C. Titration of Carbonated Beverage**

	Trial 1	Trial 2
1. Volume of Soda Used		
2. Standardized Concentration of NaOH		
3. Initial Volume NaOH		
4. Final Volume NaOH		
5. Volume NaOH Used		
6. Instructor Approval of Endpoint		
7. Mol NaOH		
8. Mol to Mol Ratio of NaOH to Citric Acid	3 NaOH : 1 Acid	3 NaOH : 1 Acid
9. Mol Citric Acid		
10. Concentration of Citric Acid in the Soda		

\*Show your work.

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

**D. Titration of Citric Acid**

	Trial 1	Trial 2	Trial 3 (only necessary if instructor does not give approval for one of the previous trials).
1. Mass of $\text{C}_6\text{H}_8\text{O}_7$			
2. Mol $\text{C}_6\text{H}_8\text{O}_7$			
3. Initial Volume NaOH			
4. Final Volume NaOH			
5. Volume NaOH Used			
6. Instructor Approval of Endpoint			
7. Mol NaOH			
8. Mol $\text{H}^+$			
9. Mol $\text{H}^+$ / mol $\text{C}_6\text{H}_8\text{O}_7$			

\*Show all calculations

Did the titration show that citric acid is triprotic? Why or why not?

Name \_\_\_\_\_

Date \_\_\_\_\_

Lab Partner \_\_\_\_\_

Bin # \_\_\_\_\_

### **PostLab Questions**

1. Why isn't it necessary to measure the volume of water added to the analyte in a titration?
2. If the stock solution of NaOH was standardized yesterday morning, is it necessary to standardize the solution today? Why or why not?
3. How could we have modified today's experiment to perform analysis on a dark soda?
4. Using the concentration of citric acid in your sample of Sprite (see page 9, line item 10.), calculate the pH of your Sprite sample.
5. Does the concentration of citric acid in your Sprite sample agree with the theoretical concentration of citric acid in Sprite (see your answer for prelab question 5)? Explain.